Nasir Ganikhodjaev
Farrukh Mukhamedov
Pah Chin Hee

VOLUME 1

$$x' = 2xy$$
$$y' = 2xz$$

INVESTIGATIONS ON PURE MATHEMATICS, FINANCE MATHEMATICS AND OPTICS

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$$\varphi_1(x, y, z) = z$$

$$z' = x^2 + y^2 + z^2 + 2yz$$

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Farrukh Mukhamedov
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QUANTUM TRAJECTORY METHOD USING MPI PARALLEL COMPUTING

Asma' Ahmad Bahari
Assist. Prof. Dr. Muhammad Salihi Abdul Hadi

Abstract. *Quantum Trajectory Method (QTM) is a numerical Monte-Carlo analysis used to solve the master equation describing the interaction between a quantum system and a Markovian reservoir. Basically, the master equation is a differential equation of the density matrix (operator) dynamics, which describes the dynamics of an "ensemble" rather than the "individual behavior" of the element of the ensemble. The implementation of QTM on the other hand, produces a single quantum trajectory which represents the evolution of the system wave function conditioned to a series of quantum jumps at random times. The evolution of the system density matrix is obtained by taking the average over many quantum trajectories. With respect to that, it has computing time disadvantage since one has to generate many trajectories to get better approximation. Fortunately, using the MPI library; the trajectories can be generated in parallel thus can significantly improve the computation time.*

1 Introduction

This project is actually studying the implementation of MPI library to parallelize the computation in Quantum Trajectory Method. The specific task chosen is this study is to reproduce the results of quantum trajectory simulation of a cavity QED laser (or microlaser) reported by Ting Kai Ling et. all. (1998). Nevertheless, in this project; the calculation is executed parallel using MPI library on a Beowulf cluster computer known as ROCKS cluster (Rocks: About, 2008). It is of interest also to study the performance of this system as an alternative parallel computing to the very expensive supercomputer such as Cray, SGI etc.

2 Quantum Trajectory Method and MPI Library

Below is a summary of the central idea of the Quantum Trajectory simulation:

$$\otimes\ p(t) = \Delta\, t \frac{\langle \bar{\Psi} c(t) | \hat{C}^{+} \hat{C} | \bar{\Psi} c(t) \rangle}{\langle \bar{\Psi} c(t) | \bar{\Psi} c(t) \rangle} \geq R \in [0,1)$$

then

$$|\bar{\Psi} c\rangle \leftarrow C |\bar{\Psi} c\rangle$$

Else

$$i\hbar \frac{d}{dt} |\bar{\Psi} c\rangle = \tilde{H} |\bar{\Psi} c\rangle$$

End if

$$t \leftarrow t + \Delta t$$

go to $\otimes$
End

Taking the average over many such quantum trajectory reproduces the result of the corresponding master equation. For example, if an ensemble of such trajectories is generated starting from the same initial state, the ensemble average of $\rho_c(t)$ is the density operator $\rho(t)$. Note however that when $\rho(t)$ comes to a steady state, $\rho_c(t)$ will not, each trajectory keeps up